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# Electromyographic Analysis of Lower Extremity Muscle Activity during Wall Squats with an Adduction Contraction in Varied Foot Positions

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# ELECTROMYOGRAPHIC ANALYSIS OF LOWER EXTREMITY MUSCLE ACTIVITY DURING WALL SQUATS WITH AN ADDUCTION CONTRACTION IN VARIED FOOT POSITIONS

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This Scholarly Project, submitted by Jill Eken, Ashlee Jesperson, and Heather Sletten in partial fulfillment of the requirements for the Degree of Doctor of Physical Therapy from the University of North Dakota, has been read by the Advisor and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Graduate School Advisor)

(Chairperson, Physical Therapy)

PERMISSION

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|---|---|
| Title | Electromyographic Analysis of Lower Extremity Muscle Activity During Wall Squats with an Adduction Contraction in Varied Foot Positions |
| Department | Physical Therapy |
| Degree | Doctor of Physical Therapy |

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Signature(s) Jim Elliott
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Date 12/18/06

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ABSTRACT

**Purpose:** The purpose of this study was to determine if an isometric hip adduction contraction and varied foot positions during a wall squat results in increased muscle recruitment of the lower extremity. **Subjects:** Eleven healthy female adult volunteers without a prior history of knee pathology participated. **Methods:** Surface electromyography (EMG) data were collected from the adductor longus (AL), vastus medialis oblique (VMO), vastus lateralis (VL), biceps femoris (BF), gastrocnemius (GN) and anterior tibialis (AT) muscles of the dominant leg for each individual during six wall squats with different treatment conditions. Experimental trials included three different rotation positions with or without simultaneous isometric hip adduction. The rotation positions included 30° internal rotation, neutral rotation, and 30° external rotation. Raw EMG data was rectified, smoothed, and normalized to a freestanding squat to 90° of knee flexion. All exercises were performed to a position of 45° knee flexion. Subjects performed three repetitions for each trial condition with a six second hold in the squat position and five seconds between reps. Each trial was separated by two minute rest periods. A one way repeated-measure analysis of variance (ANOVA) was performed to determine if the position or adductor contraction altered the EMG response. **Results:** The repeated measures ANOVA revealed a significant difference in EMG activity in five of the six muscles: AL, VMO, VL, BF, AT ($p<.05$) with adduction and rotation. In comparison to the neutral without position, muscle activity was significantly increased in

neutral with and external rotation with adduction. The GN was the only muscle that did not show a significant difference in muscle activity (p=.056). Notably, all muscle activity was lower when compared to the free standing squat. **Discussion/Conclusion:** The recruitment of the muscles under varied foot positions with an adduction component proved to be considerably increased when compared with the control position of a wall squat in neutral without adduction. Our data suggests that to recruit VMO, an adduction component in neutral or external rotation is beneficial. These results are important for clinicians who implement a rehabilitation program with a wall squat as an exercise to facilitate strengthening in the lower extremity. It is important to consider using the wall squat as a preliminary exercise to the freestanding squat due to the decrease in muscle activity demonstrated throughout our study.

# CHAPTER I

# INTRODUCTION

Knee injuries are a common ailment seen among a variety of individuals. There are many different components to a rehabilitation program. Strengthening of the quadriceps is an essential element to this program. There are many types of exercises that may be utilized in treating individuals after a knee injury. The wall squat is a common exercise for increasing strength and weight bearing during the initial stages of rehabilitation. Studies of simultaneous hip adduction during a wall squat demonstrated an increased in recruitment of the quadriceps.[1] At the same time, other studies have implied that adding a hip rotational component augments quadriceps activation during a wall squat.[1,2,3,4,5]

## Problem Statement

The wall squat is a common addition to home exercise programs of physical therapy patients. There is a limited amount of research that has incorporated both the adduction and hip rotation components during a wall squat. In order for a patient to receive optimal rehabilitation, it is essential to determine which position will recruit the muscles most effectively.

## Purpose

The purpose of this study is to determine the role of isometric hip adduction and foot alignment on EMG activity of lower extremity muscles during the wall squat.

## Significance

Knee pain and/or pathology are common indications for physical therapy. Initial treatment often includes pain relieving modalities and exercise. An exercise which recruits multiple muscles from the hip and thigh is the wall squat. This study will help define how different positioning and conditions affect muscle activity during the wall squat so physical therapists may tailor exercise programs during treatment for more effective results.

## Research Question

How is EMG activity of the leg and thigh muscles influenced by the addition of hip adduction with the feet in 30° internal rotation, neutral, and 30° external rotation?

## Null Hypotheses

1. There is no significant difference in EMG activity of the thigh and leg (adductor longus, vastus medialis oblique, vastus lateralis, biceps femoris, gastrocnemius, and anterior tibialis) when performing wall squats in varying positions of rotation with or without an isometric adduction component.

## Alternative Hypotheses

1. There is a significant difference in EMG activity of the thigh and leg (adductor longus, vastus medialis oblique, vastus lateralis, biceps femoris, gastrocnemius, and anterior tibialis) when performing wall squats in varying positions of rotation with or without an isometric adduction component.

# CHAPTER II

## LITERATURE REVIEW

Knee problems are a common cause for individuals to seek physical therapy. Knee pain is a probable indicator of knee pathology for many individuals. A frequent indirect impairment of knee pathology is muscle weakness in the affected lower extremity. After injury to the knee, intense rehabilitation is often required and involves strengthening the musculature surrounding the knee joint to provide stability and restore normal function.[2]

The lower limb is specialized to support body weight and locomotion as well as to maintain equilibrium.[6] The proximal portion of the knee joint consists of the femur which is the longest and heaviest bone in the body. The femur transmits weight from the hip to the tibia during static and dynamic movements of the lower extremity. The tibia and fibula comprise the distal knee joint. The tibia primarily supports the body's weight, whereas the fibula mainly functions as the attachment of muscles and provides stability around the ankle.[6] The patella is the third component of the knee joint complex. The patella provides a bony surface to withstand major compression forces through the quadriceps tendon.[6]

One of the major muscle groups targeted in the rehab of the lower extremity is the quadriceps. The quadriceps is comprised of the vastus medialis (VM), vastus lateralis (VL), vastus intermedius, and rectus femoris. The muscles unite and act to extend the

knee. Some of the individual muscles are reported to have more pull on the patella than others. An example is the stronger pull from the VL on the opposing VM. This leads to a major concern for physical therapists in maintaining the balance between the VM and VL. It has been demonstrated that the VM is the first muscle of the quadriceps group to atrophy and that it responds more slowly to rehabilitation than the VL, causing it to exert less force on the patella.[2] Therefore, the VM is considered to be a key muscle in patellar stability and is the only muscle which directly and actively counteracts lateral movement of the patella.[7] A typical exercise shown as one of the best for promoting activity in the oblique portion of the VM, commonly referred to as the vastus medialis oblique (VMO), is the squat with a hip adduction component.[3] The association between the VMO and an adduction component arises from the fact that the oblique fibers of the VM also connect with two other muscles: the adductor magnus and longus.[8]

Muscle recruitment and strength between genders is similar when studying single muscle units (i.e. cross-sectional area). At the same time, biomechanical differences between genders appear to predispose females to a greater number of knee injuries.[9] Numerous studies have found a link between females and anterior cruciate ligament (ACL) injuries.[9] Certain biomechanical factors for this connection include increased joint laxity in women, limb alignment such as an increased Q angle, genu recurvatum or the tendency to hyperextend the knees in static standing, and excessive tibial torsion.[9] B.L. Zeller et al [9] looked at the difference of muscle activity in men and women during the single-legged squat. This study revealed that women increased ankle dorsiflexion, ankle pronation, hip adduction, hip flexion, hip external rotation, and decreased trunk lateral flexion during the single-legged squat compared to their male counterparts. Essentially

women tend to activate the entire lower extremity leading to an increased strain on the ACL. Women rely more on the quadriceps to control the knee during dynamic movement due to weakness in hip musculature.[9]

Imbalances of patellar tracking can result in multiple pathologies including patellofemoral pain (PFP), chondromalacia patellae, patellar subluxation, and patellar tendonitis.[2] If these conditions go untreated, degenerative arthritis may be an irreversible end product. Many studies have hypothesized that medial tibial rotation can help to target and activate the VMO because when the knee extends to 90° or beyond the muscle acts as a medial tibial rotator.[2,8,10] A study by J.F Signorile et al [2] found that knee extensor activity could be affected by different combinations of knee angle and foot position. However, it is suggested that the VMO is only active during the last few degrees of extension. This may play a key role in the knee angle which is most beneficial for recruiting VMO muscle activity.[2]

The lower extremity kinetic chain is comprised of the hip, knee, and ankle joints.[11] A closed kinetic chain (CKC) exercise is where the terminal joint meets with some considerable resistance, prohibiting or restraining free motion of the distal component. In humans, the CKC is typically accomplished through weight bearing. In an open kinetic chain exercise (OKC), the foot is not in contact with a firm surface thereby allowing free motion of the distal component. Resistance is applied to the tibia, which is directly transferred to the knee.

The optimal rehabilitation program may incorporate both OKC and CKC exercises. The concept of closed chain exercises, such as wall squats, step-ups, or lunges,

are an integral part of lower extremity rehabilitation programs.[12] At the same time, CKC exercises are thought to provide some advantageous effects over OKC activities.

The CKC exercises are thought to provide better functional outcomes due to the simultaneous muscle activation across multiple joints as compared to the one joint focus provided in OKC exercises.[13] However, it is important not to generalize the term "functional." This term should not be considered merely because the underlying idea seems appropriate but rather when simulating daily activities is necessitated.[14] These activities are incorporated to help improve a patient's performance throughout their daily routine.

Another concern when developing a rehabilitation program is the safety of the knee and stresses on the joint relative to PFP. To maximize the safety of the joint, it may be beneficial to limit joint excursion from zero to approximately 45 degrees of flexion. This is because the joint is steadily increasing the amount of stress when moving from a fully extended position to 90 degrees of flexion.[14] Various studies suggest the use of both CKC and OKC exercises to return to maximal functioning. Studies suggest that incorporating both into the program will result in better quadriceps muscle torque and significantly earlier return to sports.[15,16] This improvement in muscle torque may improve the mechanics of the knee and reduce the risk for knee pathology.

The practitioner should consider different outcomes of individuals in respect to their sport and activity level.[17] The rehabilitation program may also be a subjective prognosis made by the practitioner based on what he/she feels is most appropriate. Regardless, one of the key components to the rehabilitation program is how best to incorporate both types of exercises, OKC and CKC. Closed kinetic chain exercises are

usually started around two weeks post injury/surgery. It is recommended to begin OKC exercises six weeks post injury/surgery within a range of 90° to 40° of flexion, and also in a controlled setting.[16] For this reason, it is important to start conservatively and begin with the focus on CKC exercises. As previously stated the VMO helps to stabilize the patella against a lateral pull from the lateral quadriceps muscle.[8]

Previous studies have looked at similar components during squat exercises and have specifically analyzed the activation of the VMO and VL muscles. K.R.R Coquerio et al [1] researched the effect of a hip adduction element on the VMO and vastus lateralis longus (VLL) during a free-standing semi-squat. They found a significant increase in VMO and VL muscle activity during the semi-squat with adduction as compared to semi-squat without adduction. They suggested an isometric adduction component could help to balance the medial and lateral portions of the quadriceps femoris.[1] The resulting misalignment of the patella can cause distress on the patellofemoral joint.[18] Patellofemoral pain is a well known condition that may result and is characterized by anterior knee pain and can be caused by an incorrect extensor mechanism that does not allow the patella to glide smoothly during flexion and extension activities. Activities that utilize deep flexion at the knee joint such as: stair climbing, sitting for long periods of time, and kneeling may contribute to PFP.[4] J.E Earl et al [4] report that there tends to be a decreased ratio of muscle activity between the VMO and VL in PFP patients because the VMO displays weakness. These authors compared a traditional squat at 30° to a squeeze squat. Their results showed significantly more VMO and VL muscle activity during the squeeze squat than traditional. They did not find a significant difference for the VMO:VL ratio between conditions indicating no preferential activation of VMO.

The purpose of our study is to determine if the addition of a hip adduction contraction with varied foot positions will alter the muscle activity of the lower extremities during the commonly used CKC exercise, the wall squat.

# CHAPTER III

# METHODS

This study was performed on the University of North Dakota campus in the School of Medicine and Health Sciences (UNDSMHS) Department of Physical Therapy The study was approved by the Institutional Review Board at the University of North Dakota (IRB-200603-289).

## Subjects

Subjects were recruited by word of mouth and signs posted throughout the UNDSMHS. The subjects were healthy females between the ages of 20 and 40 years old. Exclusion criteria were a history of hip or knee pathology, sensitivity to latex or isopropyl alcohol, and/or pregnancy. Eleven females ranging in age from 22 to 24 years, took part in the study. Each subject filled out a demographic survey and voluntarily consented to participate in the study (Appendix B). In addition, each subject was asked to read and sign an informed consent form prior to her participation in the study (see Appendix C). To ensure complete confidentiality and privacy, the testing was completed in a private research room. Subjects did not receive compensation for participating in this study.

## Instrumentation

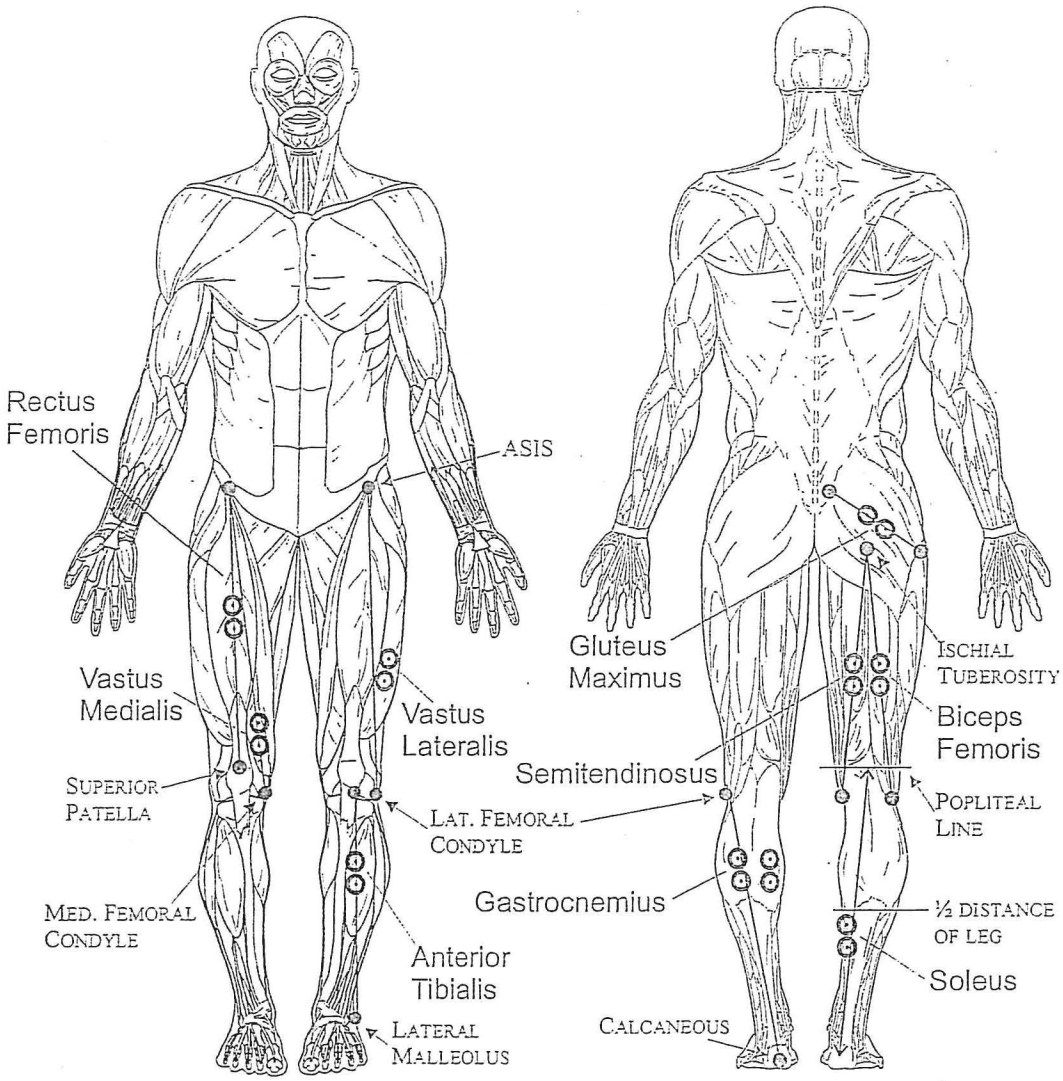
Electromyography (EMG) was used to determine the muscle activity during the wall squats. The raw EMG activity was transmitted from the telemetry transmitter to a

TeleMyo 900 (Noraxon USA, Scottsdale, AZ) receiver, which was interfaced with an analog to digital interface card (Noraxon USA), and viewed on a standard laptop computer monitor prior to saving to the hard-drive (HP Pavilion ZV5000, Pentium 4 2.80 GHz processor).

## Electrode Placement

Electrodes, Ag/AgCl (Model #272, Noraxon USA, Scottsdale, AZ) were placed using standard electrode placement charts and an inter-electrode distance of two cm (Figure 1). Origins and insertions of the muscles can be found in Table 1. Adductor longus electrodes were placed on the medial aspect of thigh in an oblique direction four cm from the pubis.[19] The VMO electrodes were placed at an oblique angle two cm medially from the superior rim of the patella on the distal third of the muscle.[19] The VL electrodes were placed along a line ¼ the distance from the lateral knee joint line to the anterior superior iliac spine and over the belly of the VL. Biceps femoris (BF) electrodes were placed at the midpoint of a line from the ischial tuberosity to the lateral femoral condyle. Gastrocnemius electrodes were placed over the muscle belly ¼ the distance of the fibular head to calcaneous. Anterior tibialis electrodes were placed over the muscle belly 1/3 the distance from the inferior patellar pole to the lateral malleolus.

Prior to electrode placement, skin was prepared in a standardized fashion including removal of hair using an electric razor and wiping of the skin surface with an isopropyl alcohol soaked towel. Skin impedance was measured (Noraxon USA) to ensure adequate conduction at each site. Each electrode was then connected to the transmitter placed around the subject's waist.




**Gluteus Maximus** - midpoint of a line running from the inferior lateral angle of the sacrum to the greater trochanter
**Biceps Femoris** - midpoint of a line from the ischial tuberosity to the lateral femoral condyle
**Semitendinosus** - midpoint of a line from the ischial tuberosity to the medial femoral condyle
**Rectus Femoris** - midpoint of a line from the ASIS to superior pole of patella (minimum of 10 cm above the patella)
**Vastus Medialis** - along a line $^{1}/_{5}$ of the distance from the medial knee joint line to the ASIS
**Vastus Lateralis** -along a line ¼ the distance from the lateral knee joint line to the ASIS and over the belly of the vastus lateralis
**Anterior Tibialis** - over the muscle belly 1/3 the distance from the inferior patellar pole to the lateral malleolus
**Peroneus Longus** - ¼ the distance from the fibular head to the lateral malleolus
**Gastrocnemius** - over the muscle belly ¼ the distance of the leg (fibular head to calcaneous)
**Soleus** - just medial to the calcaneal tendon, ½ the distance of the leg (popliteal line to calcaneous)

Figure 1 Electrode Placement for Lower Extremity Muscles

Table 1. Anatomical description of muscles assessed for EMG activity during the wall squat in varying foot positions.

| MUSCLES | ORIGIN | INSERTION | INNERVATION | ACTION |
|---|---|---|---|---|
| **Adductor Longus** | Body of the pubis | Middle of linea aspera | Obturator Nerve | Hip adduction<br>Hip flexion<br>Hip lateral rotation |
| **VMO** | Medial lip of linea aspera/ Intertrochanteric line | Top of patella/ Tibial tuberosity | Femoral Nerve | Knee extension |
| **Vastus Lateralis** | Lateral lip of linea aspera/ Greater trochanter | Top of patella/ Tibial tuberosity | Femoral Nerve | Knee extension |
| **Gastrocnemius** | Femoral Condyles | Calcaneal Tuberosity | Tibial Nerve | Plantarflexion<br>Knee flexion |
| **Anterior tibialis** | Upper ½ of tibia | 1st metatarsal and Cuneiform | Deep peroneal Nerve | Dorsiflexion<br>Inversion |
| **Biceps femoris** | Long Head: Ischial Tuberosity | Fibular head | Sciatic nerve: Tibial portion | Knee flexion<br>Thigh extension |

Adapted from: Clinically Oriented Anatomy 4th Ed.

## Data Collection Procedure

The subject's dominant leg was determined by rolling a ball to the subject and asking them to kick it back. Following placement of the electrodes, each subject performed a total of 6 wall squats to a depth of 45° knee flexion in each of 3 different foot positions—neutral, 30° internal rotation, and 30° external rotation with and without an isometric hip adduction contraction. The six test conditions were neutral without an adduction contraction (NWO), neutral with an adduction contraction (NW), external rotation without an adduction contraction (ERWO), external rotation with an adduction contraction (ERW), internal rotation without an adduction contraction (IRWO), and internal rotation with an adduction contraction (IRW). The hip adduction was accomplished by having the subject squeeze a six inch lightweight ball maximally between the knees. The position of the ball was of comfort, chosen by the subject and the contraction was held throughout the entire squat. The subject drew from six cards to randomly determine the order of foot positioning and test condition.

To standardize the depth of each squat, an adjustable bar was set to a height which corresponded to the standing distance from buttocks to the floor while the knee was flexed to 45° (measured by a goniometer). The foot distance from vertical support was determined by marking a line on the floor equal to ¾ the length of subject's fibula. The subject's heel was placed at this mark to ensure a standard foot placement. A non-slip mat was marked with tape and secured to the ground to indicate this position. The neutral position was defined as having the feet shoulder width apart with the toes perpendicular to the vertical support. Marks were also placed on the mat to indicate neutral, 30° internal rotation, and 30° external rotation (Figures 2 & 3).

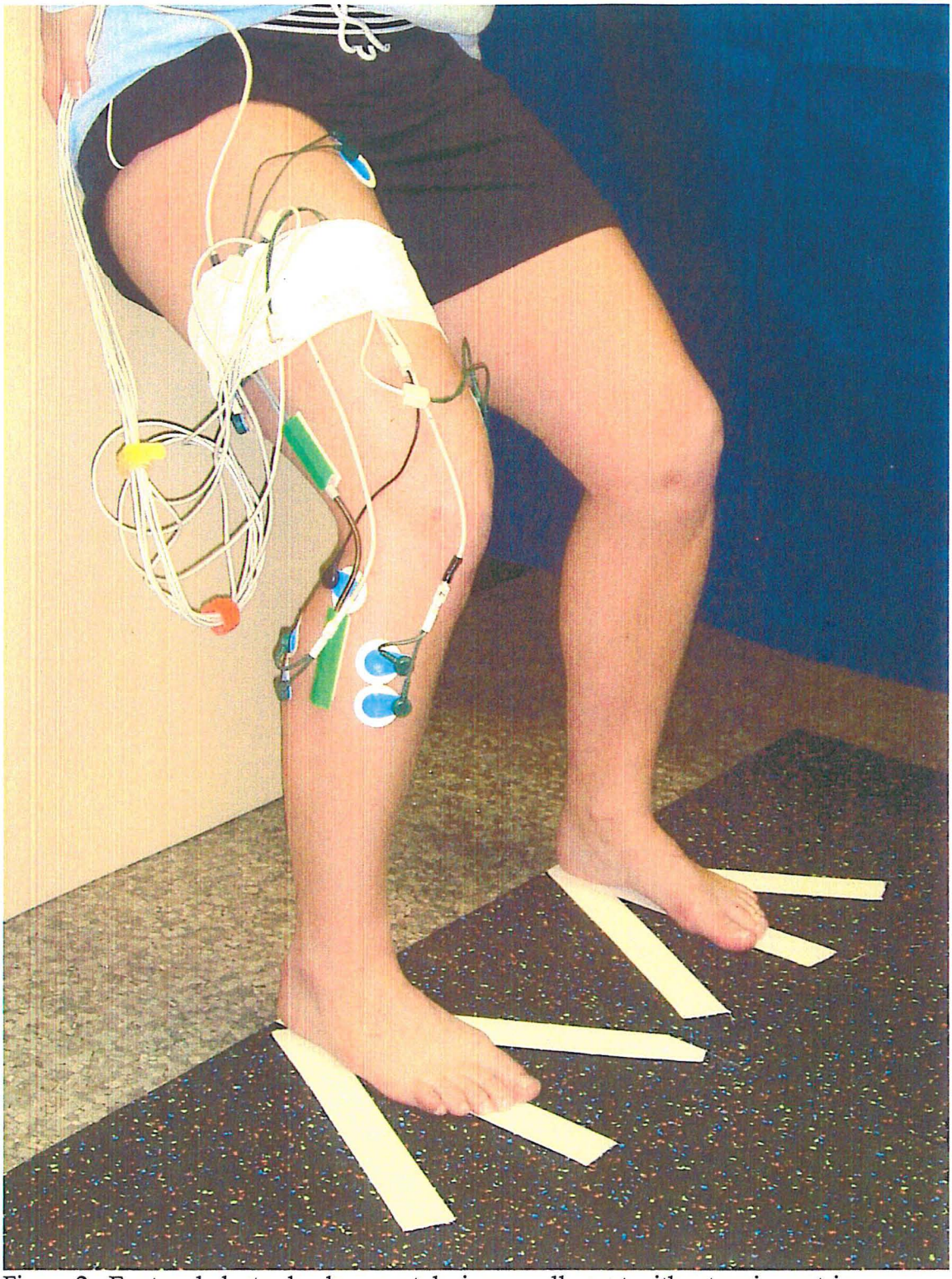


Figure 2. Foot and electrode placement during a wall squat without an isometric adduction contraction.

Figure 3. Foot and electrode placement during a wall squat with an isometric adduction contraction in 30° of external rotation.

Each subject then performed a practice repetition followed by three continuous repetitions with six second holds in the squat position. Each squat was separated by a five second rest in the upright position. A metronome set at 60 beats per minute was used for pacing the wall squat trials. One examiner instructed the subject on initiating and ending the squat by stating "up" or "down" at appropriate times. A two minute rest period was allowed between each of the 3 foot positions under each condition. Encouragement to the subject was provided by using the following statements: "hold," "squeeze," and "good job."

Removal of the electrodes was performed by the subjects wiping the area with isopropyl alcohol. No adverse reactions were observed or reported during the study.

## Data Analysis

Data analysis was performed using the MyoResearch XP (Noraxon, USA) software program. The raw EMG signals were normalized to a free-standing squat to 90 degrees of knee flexion. The maximal 1000 contiguous points of EMG activity during the freestanding squat were operationally defined as the maximum voluntary contraction (MVC). Following normalization, the signal was rectified and smoothed (RMS 50 ms) using the MyoResearch XP (Noraxon, USA) software program. The mean activity of two to three squat repetitions for each experimental trial was used for statistical analysis.

## Statistical Analysis

Data are presented as mean±standard deviation. The data were then transported into the SPSS 11.0 statistic software package for statistical analysis (SPSS, Chicago, IL). A repeated measures univariate analysis of variance (ANOVA) was utilized to determine differences between the experimental trials for each individual muscle (alpha=0.05). Only

subjects with data in all experimental trials were used for statistical analysis. The least significant difference post hoc analysis was utilized to determine individual differences within each muscle group.

# CHAPTER IV

# RESULTS

## Demographics

The subjects consisted of 11 healthy females between the ages of 22 and 24 years old with an average age of 23 and no history of knee or hip pathology. All of the females were graduate physical therapy students. The mean height was 66.5 inches with a range of 62 to 72 inches, while the mean self-reported weight was 148 pounds with a range of 124 to 170 pounds. Ten subjects were found to be right leg dominant and one subject was found to be left leg dominant.

## EMG Data Analysis

A single factor, repeated measures ANOVA indicated statistical significance (alpha=.05) in mean EMG activity between test conditions for the adductor longus [$F(1,6)=6.885$, $p=0.039$], vastus medialis oblique [$F(1,7)=4.917$, $p=0.002$], vastus lateralis [$F(1,7)=10.130$, $p=0.001$], biceps femoris [$F(1,6)=47.029$, $p=0.001$], and anterior tibialis [$F(1,7)=10.065$, $p=0.001$] (Table 2). The single factor, repeated measures ANOVA did not indicate a statistical significance for mean EMG activity across test conditions for the gastrocnemius [$F(1,6)=5.579$, $p=0.056$]. Notably, all muscle activity during the wall squat was lower than the free standing squat. The mean EMG activity of each muscle is listed in Table 3 and can be found in graphic form in Appendix A.

Table 2. Results of single factor, repeated measures analysis of variance for individual muscle groups

| **MUSCLE** | **F** | **df** | **P** | **$\eta^2$** | **Power** |
|---|---|---|---|---|---|
| Adductor Longus | 6:885 | 1,6 | 0.039 | 0.534 | 0.594 |
| VMO | 4.917 | 1,7 | 0.002 | 0.413 | 0.962 |
| VL | 10.130 | 1,7 | 0.001 | 0.591 | 1.000 |
| Biceps Femoris | 47.029 | 1,6 | 0.001 | 0.887 | 1.000 |
| Gastrocnemius | 5.579 | 1,6 | 0.056 | 0.482 | 0.509 |
| Anterior Tibialis | 10.065 | 1,7 | 0.001 | 0.590 | 1.000 |

Table 3. Mean EMG activity occurring within each type of trial

| TRIAL | Adductor Longus | VMO | VL | Biceps Femoris | Gastroc | Anterior Tibialis |
|---|---|---|---|---|---|---|
| NWO | 27.9±16.5 | 23.1±7.4 | 23.3±9.0 | 29.5±14.9 | 48.5±38.8 | 3.7±2.0 |
| NW | 64.1±38.0 | 28.9±8.5 | 32.5±11.2 | 89.8±36.8 | 3.4±2.3 | 20.2±19.5 |
| ERWO | 24.0±7.1 | 21.3±7.7 | 23.4±11.9 | 28.4±10.3 | 32.9±24.5 | 5.9±5.9 |
| ERW | 74.2±47.5 | 33.1±10.1 | 37.3±15.1 | 170.0±40.6 | 53.0±28.2 | 27.6±18.6 |
| IRWO | 26.3±16.4 | 24.6±9.6 | 25.9±13.3 | 28.1±11.1 | 55.3±26.5 | 4.0±1.9 |
| IRW | 77.0±58.2 | 29.0±12.5 | 32.3±15.8 | 47.0±28.3 | 85.0±62.9 | 11.5±8.3 |

**Note: n=7-8 subjects per muscle group.**

The adductor longus was affected by position and adduction contraction. The post hoc analysis revealed that utilization of the adductor contraction significantly increased adductor longus activity in all conditions in comparison to the respective control (i.e. NW was significantly higher than NWO). However, only the NW and ERW positions produced a significantly higher level of EMG activity compared to the control, NWO condition. See Graph 1 in Appendix A.

The VMO was affected by position and adductor contraction. The post hoc analysis for VMO revealed that the addition of an adductor contraction resulted in significant increases in activity for external rotation and neutral conditions in comparison to their respective control (i.e. ERW was significantly higher than ERWO). Both ERW and NW also produced significant increases compared to the control, NWO condition. The ERW position was found to be significantly greater than NW. Internal rotation with or without adduction contraction was not found to be significant in comparison to any of the other conditions. See Graph 2 in Appendix A.

The VL was affected by position and adductor contraction. The post hoc analysis for VL revealed a significant difference in muscle activity across test positions. The adductor contraction significantly increased VL activity in all conditions in comparison to the respective control (i.e. ERW contraction was significantly higher than ERWO). Each of the conditions including an adduction contraction showed significant increases in comparison to the control, NWO. See Graph 3 in Appendix A.

The BF was affected by position and adductor contraction. The post hoc analysis for BF revealed the adductor contraction significantly increased activity in all conditions in comparison to the respective control (i.e. NW contraction was significantly higher than NWO). However, only the NW and ERW positions resulted in a significantly higher level of activity as compared to the control. The IRW position resulted in significantly lower BF activity than both the NW and ERW positions. The ERW position showed significantly higher BF activity as compared to all other positions. NW showed the next highest level of BF activity, showing significantly higher activity than all other positions (excluding ERW). See Graph 4 in Appendix A.

The AT was affected by position and adductor contraction. The post hoc analysis for AT revealed the adductor contraction significantly increased activity in all conditions in comparison to the respective control (i.e. IRW contraction was significantly higher than IRWO). Each of the conditions including an adduction contraction showed significant increases in comparison to the control, NWO. See Graph 5 in Appendix A.

# CHAPTER V

## DISCUSSION AND CONCLUSION

Our results are in agreement with previous studies that indicate a significant increase in quadriceps muscle activity when an adduction component is added to a squat. Coquiero et al [1] reported significant increases in muscle activity of VMO and VL during a semi-squat with adduction as compared to a semi-squat without adduction. This was true for both healthy subjects and subjects with patellofemoral pain syndrome. Earl et al [4] also found similar results using a dynamic mini-squat at 30° knee flexion, which showed a 25% increase in quadriceps activity with the addition of an adduction contraction. This demonstrates that an increased recruitment is found to be maintained during submaximal dynamic performances.

Our results demonstrate significant differences in EMG activity across test conditions in all of the thigh muscles that were examined. Therefore, the null hypothesis is rejected and the alternative hypothesis is accepted. As expected with the adductor longus, significantly greater EMG activity was found in each of the conditions which included the adduction contraction. Relative to the control condition (neutral without adduction), only neutral with adduction and external rotation with adduction were found to show significant increases in muscle activity. Therefore, to optimally activate the AL, the wall squat with an adductor contraction in neutral or external hip rotation should be utilized. These would be the most ideal positions when developing exercise programs.

In order to maximally recruit VMO, our data suggests an adductor component is required in neutral or external rotation. Similar to the AL, these two positions were found to be significantly greater than the standard or control wall squat (NWO). However, the ERW position significantly increased VMO activity in comparison to the NW position. This would indicate ERW as the optimal position for maximally recruiting VMO during strengthening. Additionally, this statement holds true for optimal recruitment of both VL and BF. When considering rotation without adduction, our data has shown there to be no effect of these positions on VMO or AT muscle activity.

In lower leg musculature it was found that GN was not affected by rotation or addition of an adductor component. The AT was found to have significant differences across test conditions. Our data suggest that the NW adduction position would be most appropriate for AT recruitment. There was found to be no significant difference between neutral with adduction and either of the rotational positions.

In nearly all of the muscles we examined, utilizing an adduction contraction significantly increased muscle activity in comparison to the respective control. This may suggest that incorporating an adduction component to the wall squat would be beneficial in maximally recruiting multiple muscles. VMO was the only exception in that internal rotation was not found to be significant in comparing with to without the adduction contraction. Hodges and Richardson [10] also demonstrated a significant difference in muscle recruitment with the addition of an adduction component during a semi-squat position. However, unlike our study, adductor magnus was used rather than adductor longus. Their results showed a greater increase in VMO activation as compared to VL.

While the present study is the first to combine the effects of adduction and rotation, previous investigators have observed independent effects of rotation and adduction. This was based on findings from another study that indicated significant differences in BF, GN, and AT based on foot position. Beach J et al [20] demonstrated increased thigh and leg muscle EMG activity when performing a wall squat with internal or external rotation. The BF and AT showed significant increases in activity during external rotation. They found significant increases of GN muscle activity during internal rotation.

Our study incorporated a rotational component where the participants' foot positions were placed either in neutral, 30° of external rotation, or 30° of internal rotation. Lam et al [5] designed a study that included different combinations of hip rotation at varied degrees of knee flexion. The subjects performed a freestanding semi-squat on two different bathroom scales marked with colored tape. The colored tape signified either a neutral position, 30 degrees of internal rotation, or 45 degrees of external rotation. Subjects then performed the squat at 20 degrees of knee flexion then at 40 degrees of knee flexion. The results of this study showed a higher EMG activity for the VMO when the medial hip component was combined with 40 degrees of knee flexion. Our study differed in the fact that our results lead us to believe that the external rotation position with a hip adduction contraction maximized the muscle activity for the VMO. This major difference could be due to the fact that the study performed by Lam et al. did not include an adduction component along with the varied foot positions whereas ours was looking at both a rotational and adduction component.

Even though there was a significant increase in EMG activity across test conditions, lower extremity recruitment was notably decreased in comparison to the freestanding squat. This may be due to stabilization of the trunk against the wall reducing the amount of work required by the lower extremity. This leads us to believe that the wall squat would be an appropriate preliminary activity to the freestanding squat during rehabilitation of the knee.

## Limitations & Considerations

As with any study, future considerations should be addressed to further define other relevant questions. Our study examined the variability in the firing rate of certain muscles of the LE during a wall squat in varied foot positions. The main purpose was to determine the effects of various positions on the amount of muscle activity. Future studies may want to look at comparing muscle activity between muscles, specifically the ratio of VM to VL. This may help clarify the ideal position for overall balance of the quadriceps.

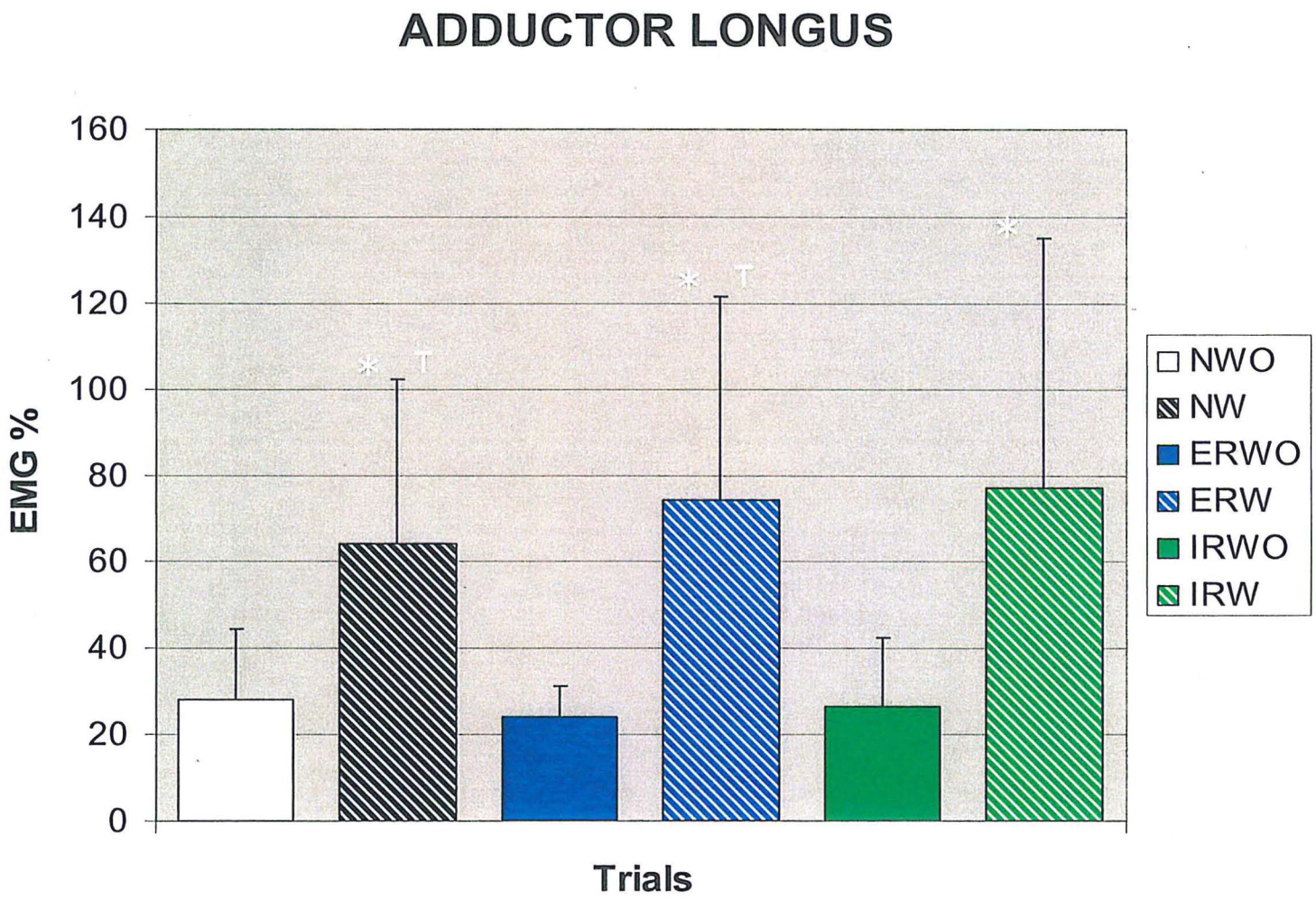
One major limitation to our study may be sample size. We utilized a small sample and collected data from 11 subjects. This became even more limited when analyzing the data since certain outliers were removed. A larger sample size would have provided greater power when assessing significance between EMG activity. In conjunction, another limitation may be that our sample was very homogeneous. We chose to use healthy subjects with no history of hip or knee pathology. Future research may consider using subjects with knee pathologies such as PFP. Other research has suggested that with knee pathology, muscles may be recruited differently during strengthening activities.[10]

An additional limitation may have been the force of the adduction contraction. Subjects were allowed to choose their own amount of force. They were instructed to squeeze with a maximal contraction but we did not measure the force to standardize and ensure maximal effort. The amount of standard deviation seen in our study was quite variable. Controlling the amount of adduction force may have helped to decrease the standard deviation and improve power. Carry-over effects or progressive error such as fatigue may also have contributed to error. Subjects were required to perform three reps of each test condition for a total of 18 reps. Each of the repetitions involved a five second hold which may have proved to require more energy and effort depending on individual lower extremity conditioning.

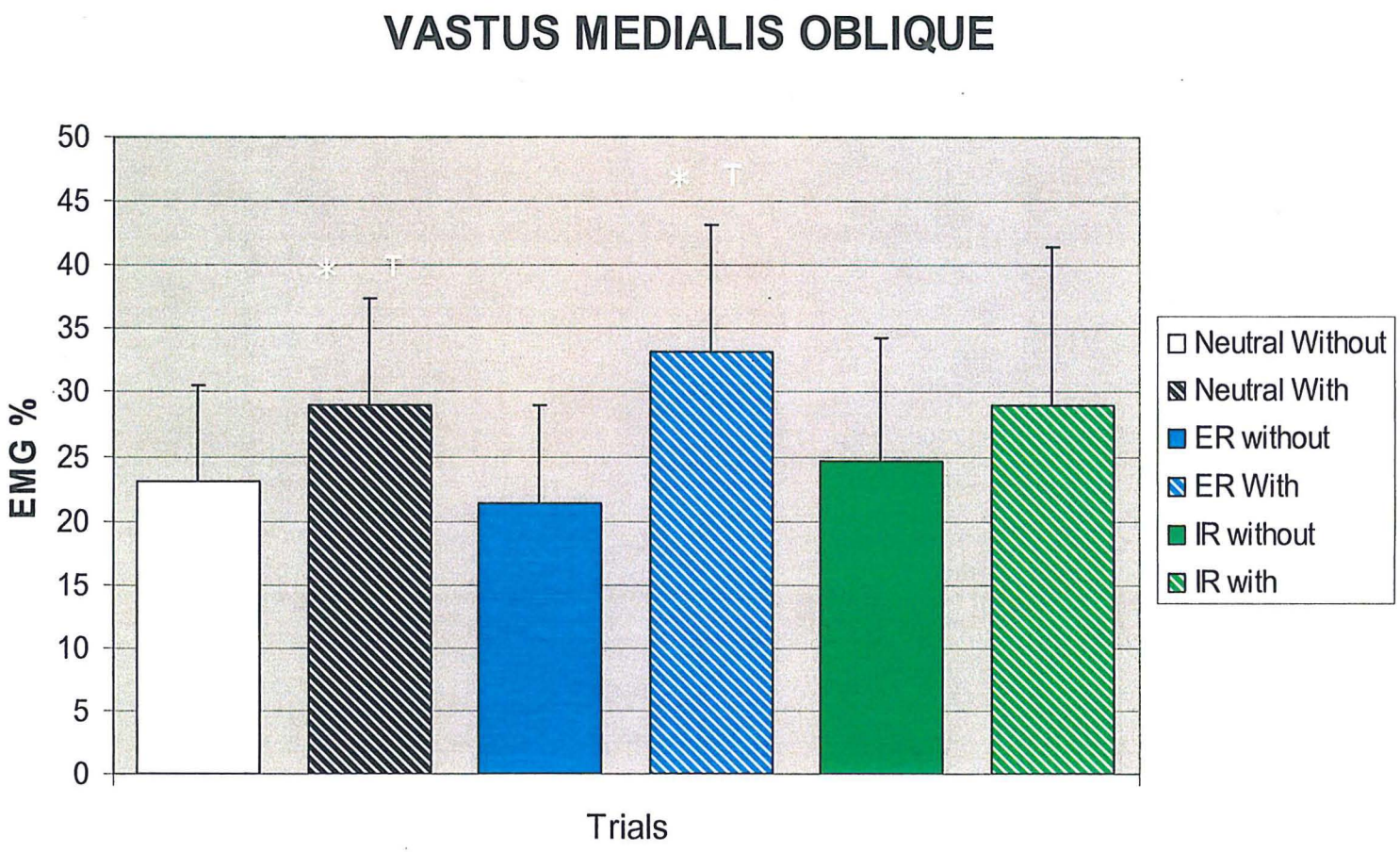
## Conclusion

Our results were statistically significant for reporting a difference in EMG activity between muscles during an adduction contraction in varied foot positions. The recruitment of the muscles under varied foot positions with an adduction component proved to be considerably increased when compared with the control position of a wall squat in neutral without adduction. Due to its role, or lack thereof, in patients with knee pathology, the VMO is a very important muscle in the knee complex. The position we found to increase the firing rate of the VMO the most was during the wall squat with external rotation and an adduction component. These results are important for clinicians who implement a rehabilitation program with a wall squat as an exercise to facilitate strengthening in the lower extremity.

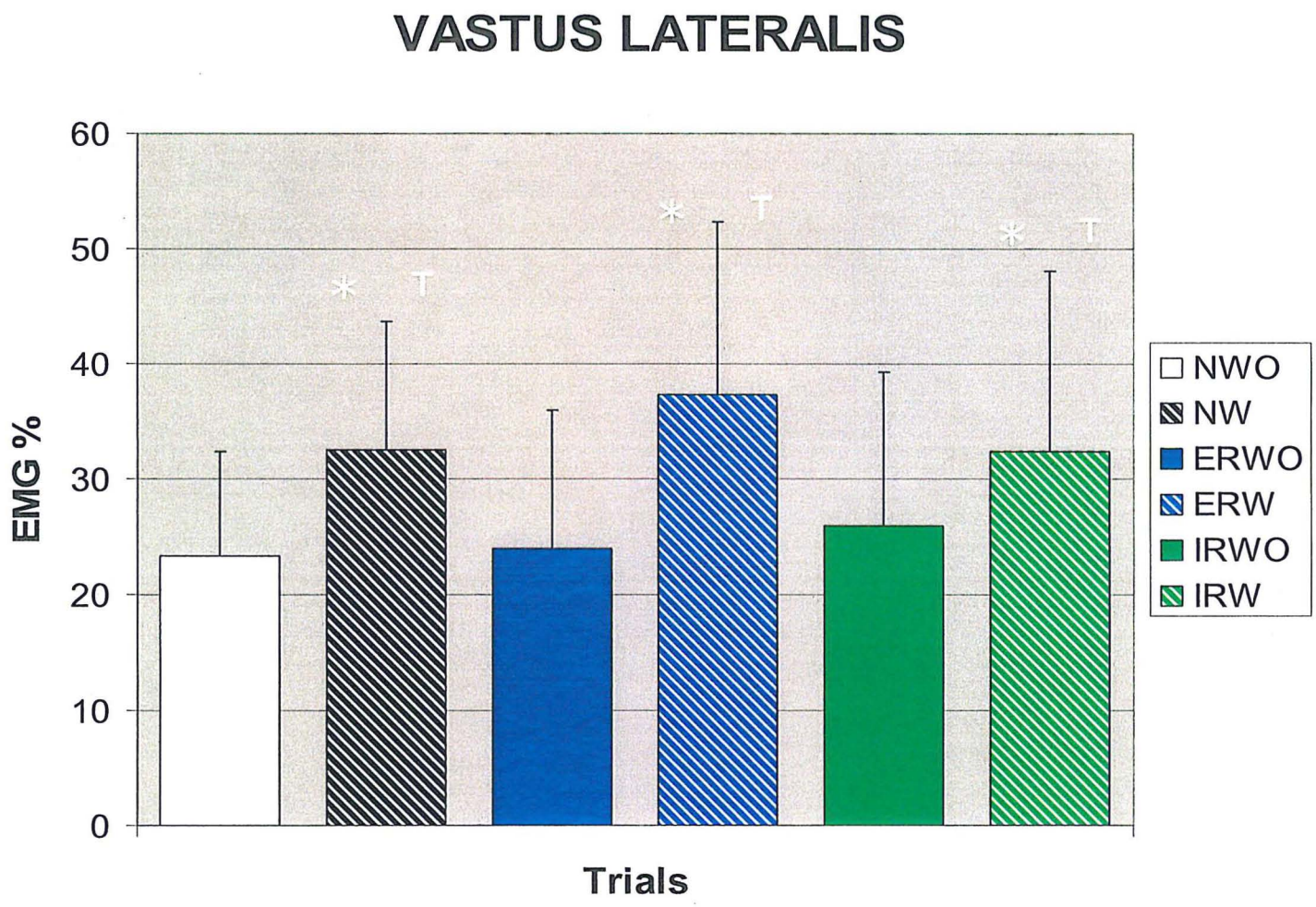
# APPENDIX A



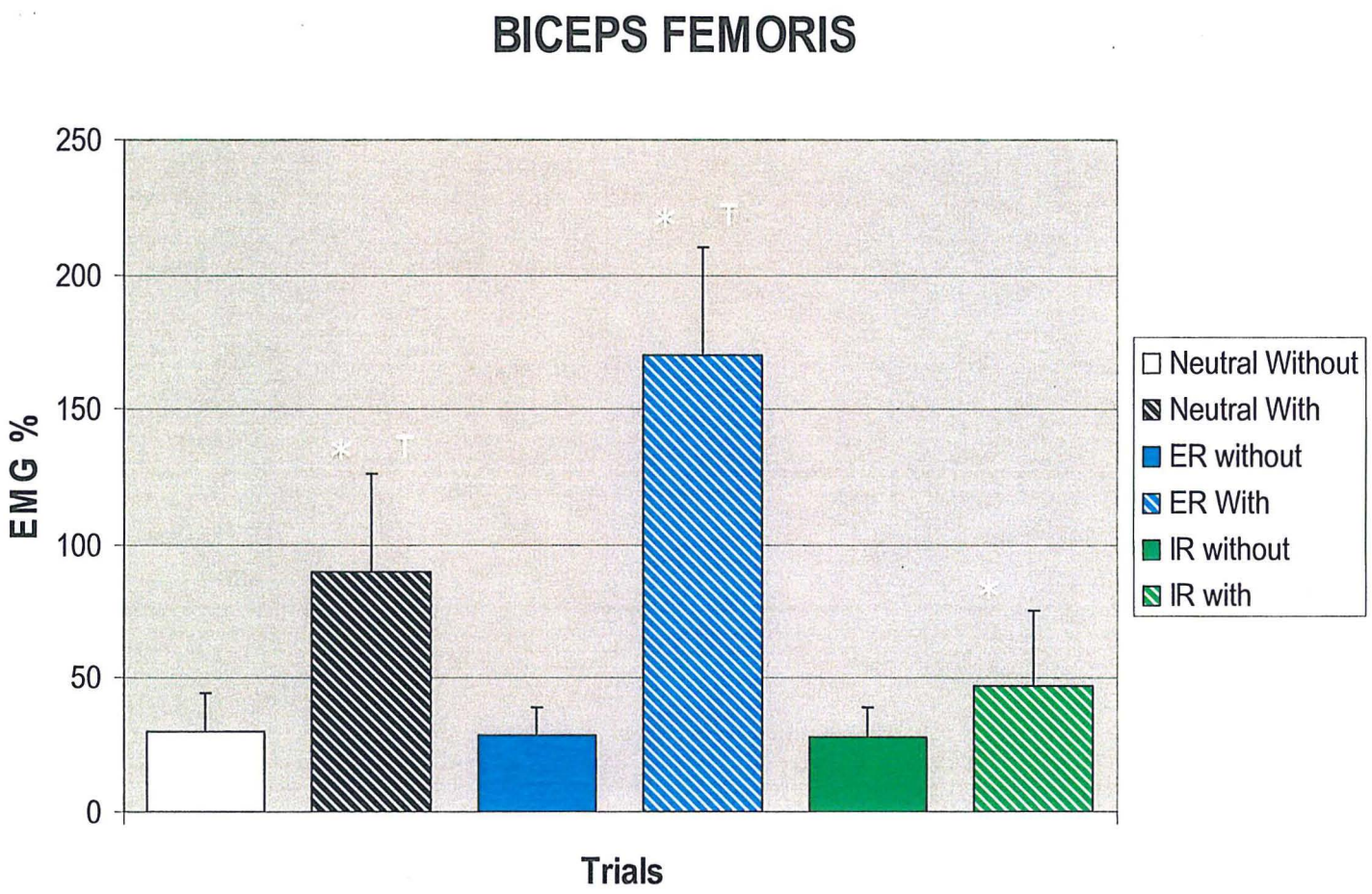

Graph 1. Mean EMG activity of AL within each trial. * indicates a significant difference of the indicated position from the respective control. T indicates a significant difference from NWO.



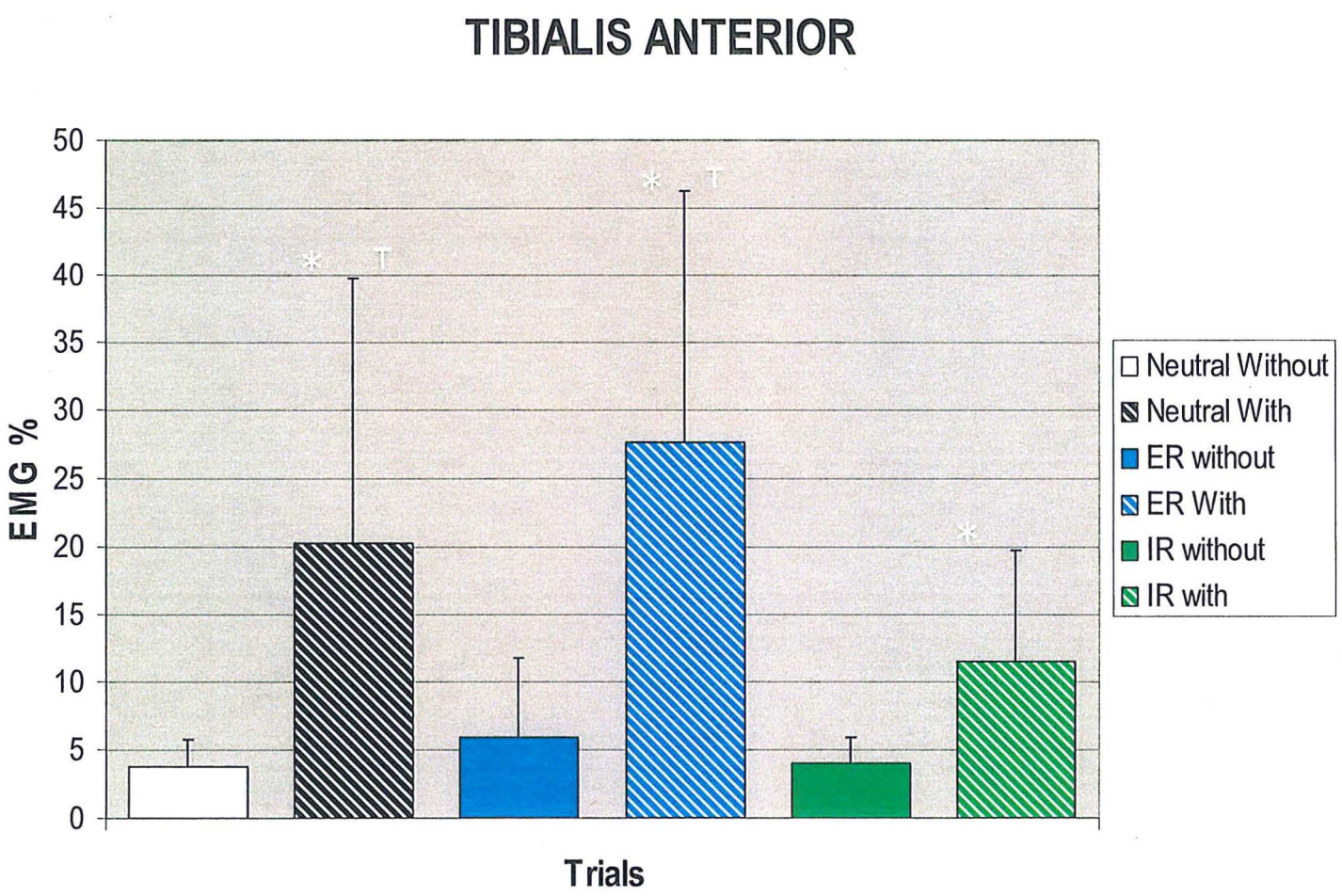

Graph 2. Mean EMG activity of VMO within each trial. * indicates a significant difference of the indicated position from the respective control. T indicates a significant difference from NWO.




Graph 3. Mean EMG activity of VL within each trial. * indicates a significant difference of the indicated position from the respective control. T indicates a significant difference from NWO.




Graph 4. Mean EMG activity of BF within each trial. * indicates a significant difference of the indicated position from the respective control. T indicates a significant difference from NWO.




Graph 5. Mean EMG activity of AT within each trial. * indicates a significant difference of the indicated position from the respective control. T indicates a significant difference from NWO.

# APPENDIX B

## Subject Demographic Information:

ID # _____ Gender: M or F

Name: _____ Educational Major: _____

Age: _____ Academic Grade Level: _____

Height: _____inch Dominant Leg: _____
(Leg used to kick a ball)

Weight: _____lbs

1. Have you ever had any previous knee problems? Y or N (Circle one)

   If yes, please describe what problems and when did they occur?

   _____

   _____

2. Do you have any latex or isopropyl (rubbing) alcohol allergies? Y or N (circle one)

   If yes, please describe:

   _____

   _____

   _____

3. Please describe your usual physical activities performed in a typical week? (i.e. work, exercise, etc)

   _____

   _____

   _____

SQUAT STUDY DATA COLLECTION FORM

ID# _____

Age_____ Height (cm) _____ Weight (kg) _____

Marker size: 9 mm 12 mm 14 mm 20 mm

SUBJECT MEASUREMENTS:

**Shoulder offset:** _____ cm

*vertical offset from the base of the acromion marker to shoulder joint Center*

**Elbow width:** _____ cm

*width of elbow along flexion axis between distal epicondyles*

**Wrist width:** _____ cm

*anterior posterior thickness of wrist at position where wrist marker bar is attached.*

**Hand thickness:** _____ cm

*anterior-posterior thickness between the dorsum and palmer surface of the hand*

**Leg length:** _____ cm

*distance between ASIS and the medial malleolus.*

**Knee width:** _____ cm

*the medial lateral width of the knee across the line of the knee axis measured in standing.*

**Ankle width:** _____ cm

*the medial lateral distance across the malleoli in standing.*

**Maximal Adduction Force:** _____psi

| Trial | Adduction | | | | Rotation | | | |
|---|---|---|---|---|---|---|---|---|
| | 75% | 50% | 25% | | Neutral | Internal | External | |
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# APPENDIX C

ID#_____

Consent to Participate in Research

Motion Analysis and EMG Analysis of Lower Extremity Muscle Activity During Wall Squats with an Adduction Contraction in Varied Foot Positions

You are invited to voluntarily participate in a research project conducted by faculty and students of the UND Department of Physical Therapy: David Relling, PT, PhD, Sue Jeno, PT, PhD, Renee Mabey, PT, PhD, Tom Mohr, PT, PhD, Mark Romanick, PT, PhD, and DPT students Ashlee Jesperson, Heather Sletten, and Jill Eken. This study is being conducted to determine if the addition of a hip adduction isometric contraction during a wall squat with feet in different positions will alter the muscle activity in muscles of the lower extremity or change the mechanics of the squat. The conclusions drawn from this study will allow practicing clinicians to better personalize the exercise programs provided to their clients with knee pathology. Only healthy persons between the ages of 20-40 years, without history of hip or knee pathology or sensitivity to latex or isopropyl alcohol will be allowed to participate in this study. Participation in this study should take no longer than 60 minutes during 1 data collection session.

EMG activity of the muscles of the lower extremities will be monitored during the squat activities with the use of pre-gelled, self-adhesive electrodes placed over the muscles in your dominant leg. Excess hair in the area where the electrodes will be positioned will be shaved with an electric razor and cleaned with alcohol wipes before electrodes are placed on your skin. The electrodes will be attached to a transmitter located in a belt at your waist. EMG signals are sent to the computer for analysis. Reflective motion analysis markers will be placed on your skin at several locations on the pelvis and lower extremities which will allow the cameras positioned in front, behind, and to the side of you to capture your motion as you perform a squat activity. Motion analysis data is sent directly to the computer for analysis, no video recording is made of your movement.

Once the markers are in place, you will be asked to perform a maximal isometric contraction of your hip adductors and a standing squat to a depth of 45° of knee flexion to allow for muscle activity comparison. You will be asked to perform a series of 3 wall squats to a depth of 45° of knee flexion using 3 different foot positions under 2 different test conditions – with and without an isometric hip adduction contraction. The adduction contraction during the trials will require you to squeeze a 6" lightweight ball between you knees while you perform the wall squat. Foot positions will include neutral position, 30° of external rotation, and 30° of internal rotation. Each position will be assigned a number and you will draw from 6 cards to randomly determine the order of foot positioning and test condition. You will perform 1 practice repetition followed by 3 continuous repetitions of 6 second holds and 5 second rests. A metronome will be used for pacing the wall squat trials. You will be given 2 minute rest between each trial.

The benefits of this study to you as a participant include but are not limited to 1) gaining a better understanding of the muscle activity and lower extremity motion used during the wall squat activity and 2) increasing the current level of knowledge of muscle activity and motion patterns of the lower extremities during this activity. There will be neither cost associated with nor any compensation to you for contributing to this study.

Although there is some degree of risk involved in physical activity testing, the researchers believe the risk of injury and discomfort is minimal; however, minor muscle soreness

may occur following repeated activity. The use of non-slip surfaces and spotters will minimize any risk from loss of balance during the activity. In order to get an accurate recording of your muscle activity, the areas where electrodes will be placed will have any excess hair removed with an electric razor and be cleaned with isopropyl alcohol. Reddening of the skin in the areas where the electrodes or reflective markers are placed is possible due to the adhesive material. The EMG equipment will only monitor muscle activity, motion analysis equipment only records your movements and neither piece of equipment will cause discomfort. If at any time you experience pain, discomfort, fatigue, or any other uncomfortable symptoms, you may stop your participation in this study. All investigators are CPR certified. If an injury were to occur, medical treatment will be provided to you as needed, including first aid, CPR, and follow-up care as that provided to a member of the general public in a similar circumstance. You or your third party payer will be responsible for all incurred medical expenses.

Your name will not be used in any reports of the results of this study. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. A number known only to the investigators will identify the data. The data and records collected in this study will be kept in separate locked file cabinets for 3 years following the completion of this study and will be shredded after that time. "Only the researchers and people who audit IRB procedures will have access to the data." Your decision whether or not to participate will not prejudice your future relationship with the UND Department of Physical Therapy. If you decide to participate, you are free to discontinue participation at any time without prejudice by notifying the researchers of your decision to discontinue. The researchers reserve the right to terminate your participation in the study if you are unable to perform the testing procedures or if it is felt that continuation might lead to increased risk of injury. You may obtain a copy of the results of this study by contacting any of the researchers.

The investigators involved are available to answer any questions you have concerning the study. In addition, you are encouraged to ask any questions concerning this study that you may have in the future. If you have any questions about the research, please call Dr. Sue Jeno or Dr. David Relling at 777-2831. If you have any other questions or concerns, please call Research Development and Compliance at 777-4279.

**I have read the above information, all of my questions have been answered, I have a complete understanding of what is expected of me, and willingly agree to participate in this study. I have received a copy of this consent form for my records.**

_____

Subject's Signature Date

# APPENDIX D

**University of North Dakota Human Subjects Review Form**

All research with human participants conducted by faculty, staff, and students associated with the University of North Dakota, must be reviewed and approved as prescribed by the University's policies and procedures governing the use of human subjects. It is the intent of the University of North Dakota (UND), through the Institutional Review Board (IRB) and Research Development and Compliance (RD&C), to assist investigators engaged in human subject research to conduct their research along ethical guidelines reflecting professional as well as community standards. The University has an obligation to ensure that all research involving human subjects meets regulations established by the United States Code of Federal Regulations (CFR). When completing the Human Subjects Review Form, use the "IRB Checklist" for additional guidance.

Please provide the information requested below:

**Principal Investigator:** David Relling, Sue Jeno, Mark Romanick, Renee Mabey, Tom Mohr, Ashlee Jesperson, Heather Sletten, Jill Eken

Telephone: 777-2831 E-mail Address: sujeno@medicine.nodak.edu

Complete Mailing Address: Box 9037

School/College: SOMHS Department: Physical Therapy

**Student Adviser (if applicable):**

Telephone: E-mail Address:

Address or Box #:

School/College: Department:

Project Title: Motion Analysis and EMG Analysis of Lower Extremity Muscle Activity During Wall Squats with an Adduction Contraction in Varied Foot Positions

**Proposed Project Dates:** Beginning Date: 3/15/06 Completion Date: 5/15/07 (Including data analysis

**Funding agencies supporting this research:** UND Physical Therapy Department

*(A copy of the funding proposal for each agency identified above MUST be attached to this proposal when submitted.)*

___ YES or _X_ NO Does the Principal Investigator or any researcher associated with this project have a financial interest in the results of this project? If yes, please submit, on a separate piece of paper, an additional explanation of the financial interest (other than of a grant)

If your project has been or will be submitted to other IRBs, list those Boards below, along with the status of each proposal.

_____ Date submitted: _____ Status: ___ Approved ___ Pend

_____ Date submitted: _____ Status: ___ Approved ___ Pend

**Type of Project:** Check "Yes" or "No" for each of the following.

_X_ YES or ___ NO New Project

___ YES or ___ NO Continuation/Renewal

___ YES or _X_ NO Dissertation/Thesis

___ YES or _X_ NO Student Research Project

___ YES or _X_ NO Is this a Protocol Change for previously approved project? If yes, submit a signed copy of this form with the changes bolded or highlighted.

___ YES or _X_ NO Does your project involve medical record information? If yes, complete the HIPAA Compliance Application and submit it with this form.

___ YES or _X_ NO Does your project include Genetic Research? If yes, refer to Chapter 3 of the Researcher Handbook for additional guidelines regarding your topic.

___ YES or _X_ NO Does your project include Internet Research? If yes, refer to Chapter 3 of the Researcher Handbook for additional guidelines regarding your topic.

___ YES or _X_ NO Will subjects or data be provided by Altru Health Systems? If yes, submit two copies of the proposal. A copy of the proposal will be provided to Altru.

____ YES or __X__ NO Will research subjects be recruited at another organization (e.g., hospitals, schools, YMCA) or will assistance with the collection be obtained from another organization?

If yes, list all institutions: _____

Letters from each organization must accompany this proposal. Each letter must illustrate that the organization understands their involvement in that study, and agrees to participate in the study. Letters must include the name and title of the individual signing the letter and, if possible, should be printed on letterhead.

**Subject Classification:** This study will involve subjects who are in the following special populations: Check all that apply.

_____ Minors (< 18 years)
__X__ UND Students
_____ Prisoners
_____ Pregnant Women/Fetuses
_____ Persons with impaired ability to understand their involvement and/or consequences of participation in this research
_____ Other _____

**For information about protections for each of the special populations, refer to Chapter 5 of the Researcher Handbook.**

**This study will involve:** Check all that apply.

_____ Deception
_____ Radiation
_____ New Drugs (IND)
_____ Non-approved Use of Drug(s)
_____ Recombinant DNA
__X__ None of the above will be involved in this study
_____ Stem Cells
_____ Discarded Tissue
_____ Fetal Tissue
_____ Human Blood or Fluids
Other _____

**I. Project Overview**

Please provide a brief explanation (limit to 200 words or less) of the rationale and purpose of the study, introduction of any sponsor(s) of the study, and justification for use of human subjects and/or special populations (e.g., vulnerable populations such as minors, prisoners, pregnant women/fetuses).

Knee pain and/or pathology are common indications for patients to be referred to a physical therapy clinic. While the source of the pathology may vary between patients, many of the exercises prescribed by therapists are consistent across different diagnostic categories. One of the early weight bearing activities initiated for patients with knee pathology is the wall squat. The primary muscles used during the wall squat activity are the quadriceps, which include vastus medialis, vastus lateralis, vastus intermedius and rectus femoris. Preliminary studies have shown that in non-weight bearing activities, the addition of a hip adduction contraction prior to activation of the quadriceps muscle group strengthened the contraction of the vastus medialis muscle. A pilot study of the wall squat activity indicated no difference in muscle activity of the quadriceps muscle group relative to foot position. The purpose of this study is to determine if the addition of a hip adduction isometric contraction during a wall squat in varied foot positions will alter the muscle activity in muscles of the lower extremity or change the mechanics of the squat. Human subjects are required for this study as the information obtained will be directly applicable to patients in the clinic. Results of this study will provide information that clinicians can utilize in the development of patient specific exercise programs.

**II. Protocol Description**

Please provide a succinct description of the procedures to be used by addressing the instructions under each of the following categories. Individuals conducting clinical research please refer to the "Guidelines for Clinical-Research Protocols" on the Research and Program Development website.

**1. Subject Selection.**

a) Describe recruitment procedures (i.e., how subjects will be recruited, who will recruit them, where and when they will be recruited and for how long) and include copies of any advertisements, fliers, etc., that will be used to recruit subjects. If incentive payments will be made to anyone for enrolling participants, describe the incentive package.

Investigators will voluntarily recruit subjects through fliers posted throughout the SOMHS during the months of March 2006 through August 2006. No incentives will be provided to participants in this study. See attached flier.

b) Describe your subject selection procedures and criteria, paying special attention to the rationale for including subjects from any of the categories listed in the "Subject Classification" section above.

It is anticipated that 30-40 healthy UND students between 20-40 years of age without history of hip or knee pathology will be recruited for this study.

c) Describe your exclusionary criteria and provide a rationale for excluding subject categories.

Exclusion criteria for this study include: 1) history of knee pathology or current knee pain - differences in electrical activity and functional movements associated with knee pain and pathology could alter the patterns demonstrated during the testing

procedure; 2) history of hip pathology - subjects will be asked to perform an isometric contraction of the hip adductors which may exacerbate previous pathologies; 3) age of subjects less than 20 years or greater than 40 years. Differences in muscle physiology in younger and older individuals could enhance variability between subjects; 4) sensitivity to isopropyl alcohol or latex - electrodes used during the procedure may contain trace amounts of latex; skin is cleaned with isopropyl alcohol; in an effort to avoid adverse reactions, individuals with these sensitivities will be excluded from participation in this study.

d) Describe the estimated number of subjects that will participate and the rationale for using that number of subjects.

Thirty to 40 subjects will be recruited to decrease the risk of research error associated with smaller sample sizes.

e) Specify the potential for valid results. If you have used a power analysis to determine the number of subjects, describe your method.

Valid results are anticipated with a sample size of 30-40 subjects and randomization of the order of the foot position during the testing protocol to minimize the error associated with training effects or fatigue.

2. Description of Methodology.

a) Describe the procedures used to obtain informed consent.

Informed consent will be obtained from each subject through the information and consent form (see attached form). All individuals participating in this study will be capable of independent decision making and will sign a consent form stating their understanding and willingness to participate in this study. A copy of the consent form will be provided for each subject.

b) Describe where the research will be conducted. Document the resources and facilities to be used to carry out the proposed research. Please note staffing, funding, and space available to conduct this research.

All data collection will occur within the Department of Physical Therapy at the University of North Dakota.

c) Indicate who will carry out the research procedures.

The research procedures will be carried out by Drs. David Relling, Sue Jeno, Mark Romanick, Tom Mohr, and Physical Therapy Doctoral Students Ashlee Jesperson, Heather Sletten, Jill Eken.

d) Briefly describe the procedures and techniques to be used and the amount of time that is required by the subjects to complete them.

EMG activity of the muscles of the lower extremities will be monitored during the squat activities with the use of pre-gelled, self-adhesive electrodes placed over the motor points of the relevant muscles. The muscles to be monitored include vastus medialis oblique (VMO), adductor longus, vastus lateralis, gastrocnemius, tibialis anterior, and biceps femoris of the subject's dominant leg. Precise electrode placement will be determined by standard electrode placement charts (see attached diagram). The subjects will be asked to wear shorts to facilitate access to the muscles and protect modesty. Prior to electrode placement, the skin will be prepared in standardized fashion and skin impedance will be measured to ensure adequate electrical conduction at each site. Preparation of the skin includes removing excess hair from the electrode site with an electric razor and wiping the skin surface with an isopropyl alcohol wipe. The electrodes will be connected to a transmitter which will be placed in a belt around the subject's waist. The EMG signals will be transmitted to a receiver and then to a computer. Raw EMG data will be obtained for analysis. An unloaded, free standing squat to the same knee position (45° knee flexion) with the feet in neutral position will be used for normalization of EMG data. To facilitate motion analysis, self-adhesive reflective markers will be placed bilaterally over the subject's anterior superior iliac spine, posterior superior iliac spine, greater trochanter, patella, lateral joint line, anterior distal tibia, and lateral malleolus. Six to 8 motion analysis cameras will be placed around each subject while they perform the squat activity. Each subject will perform wall squats to a depth of 45° of knee flexion in each of 3 different foot positions – neutral, 30° hip external rotation, 30° hip internal rotation with and without an isometric contraction of the hip adductor muscles. The hip adduction will be accomplished by having the subject squeeze a 6 inch light-weight ball between his/her knees. The contraction will be maintained throughout the squat activity. A maximal isometric contraction of the hip adductor muscles will be performed by each subject. This measurement will be used to determine the level of the adduction contraction the subject will perform during the wall squat with adduction trials.

To standardize the depth of each squat, the height of an adjustable bar will be set to the height which corresponds to the standing distance from buttocks to floor while the knee is flexed to a 45° angle (as measured by a standard goniometer). This bar will be placed behind the subject to indicate the amount of movement required during each squat activity. The foot distance from the vertical support will be determined by marking a line on the floor that is equal to ¾ the length of the subject's fibula. The subject's heels will be aligned with this mark to maintain a standard foot placement during the squat activity. Neutral position will be defined as having the feet shoulder width apart, the toes perpendicular to the vertical support. Marks will be placed on non-skid mats placed on the floor indicating 30° of internal rotation, 30° of external rotation, and neutral position. Each position will be assigned a number and the subject will draw from 6 cards to randomly determine the order of foot positioning and test condition.

Subjects will perform 1 practice repetition followed by 3 continuous repetitions of 6 second holds and 5 second rests. A metronome set will be used for pacing the wall squat trials. Data will be collected throughout the full range of motion during the wall squats for each subject. There will be a 2 minute rest period between each of the 3 foot position trials under each condition. Following completion of the data collection, electrodes and reflective markers will be removed from the subject's leg using proper removal technique. This will conclude the subject's participation in the study. Results of the study will be made available at the

subject's request. EMG data will be statistically analyzed and linked with the motion analysis data for reporting of the results. It is anticipated that participation in this study will take no longer than 60 minutes per subject.

e) Describe audio/visual procedures and proper disposal of tapes.

Data collected through the motion analysis cameras is directly linked to the computer for analysis. All visual data is converted to stick figures for analysis by the computer software. No actual video recordings are made of the subject.

f) Describe the qualifications of the individuals conducting all procedures used in the study.

All researchers are faculty members in the Department of Physical Therapy and are trained in the use of EMG and motion analysis equipment.

g) Describe compensation procedures (payment or class credit for the subjects, etc.).

There will be no compensation given to subjects involved in this study.

Attachments Necessary: Copies of all instruments (such as survey/interview questions, data collection forms completed by subjects, etc.) must be attached to this proposal.

**3. Risk Identification.**

a) Clearly describe the anticipated risks to the subject/others including any physical, emotional, and financial risks that might result from this study.

The potential physical risks associated with this study are minimal. The EMG electrode placement and analysis is a non-invasive procedure utilized in clinical practice. Motion analysis requires the placement of self-adhesive markers on the skin surface which is a non-invasive procedure. During the performance of the wall slide activity, there is a slight chance the subject may lose balance or knee pain may occur. This potential risk will be minimized by the use of non-skid floor mats and the presence of a spotter during the activity. Minor skin irritation from the skin preparation and EMG electrodes/reflective markers is possible. Subjects may experience slight fatigue or muscle soreness following participation in this study but it is anticipated that this would not be any worse than that experienced during minimal physical exercise. All subjects will be healthy with no history of knee/hip pathology so these risks are minimized by inclusion/exclusion criteria.

b) Indicate whether there will be a way to link subject responses and/or data sheets to consent forms, and if so, what the justification is for having that link.

Subject's names will not be used in any reports of the results of this study. Each participant will be assigned an identification number, known only by the investigators, which will be the only association between consent forms and data collected by EMG or motion analysis. Any information that is obtained in connection with this study and that can be identified with the subject will remain confidential and will be disclosed only with permission from the subject. At the completion of the study, the research data and the consent forms will be stored in separate locked locations in the Department of Physical Therapy for 3 years at which point the forms will be shredded. Data will be reported in aggregate form only to protect the confidentiality of all subjects.

**4. Subject Protection.**

a) Describe precautions you will take to minimize potential risks to the subjects (e.g., sterile conditions, informing subjects that some individuals may have strong emotional reactions to the procedures, debriefing, etc.).

Selection of the subject pool utilizing the exclusion criteria will minimize the risks associated with this study. Limiting the squat to 45° of knee flexion will also limit potential risks of knee pain associated with deep knee squats. Muscle soreness will be minimized by limiting the number of repetitions in each position. The possibility of skin irritation will be minimized by proper skin preparation and subject screening prior to participation. To protect confidentiality and modesty, all data collection will occur in a private room. The investigators or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to his/her health. All subjects will be allowed to terminate their participation in this study at any time without prejudice.

b) Describe procedures you will implement to protect confidentiality (such as coding subject data, removing identifying information, reporting data in aggregate form, etc.).

Subject and result information will not be linked to the consent form in order to protect the confidentiality of the subjects. Names will not be associated with data collection forms. Subjects will be assigned a confidential, unique number which will be used for identification purposes. To protect confidentiality and modesty, all data collection will occur in a private room.

c) Indicate that the subject will be provided with a copy of the consent form and how this will be done.

Prior to participation in this study, each subject will read and sign a consent form. Participants in this study will all be capable of independent decision making and will sign a consent form stating their understanding and willingness to participate in this

study. Participants will be encouraged to ask any questions regarding the consent form to ensure their understanding of the document. Each participant will be given a copy of the signed consent form for their records.

d) Describe the protocol regarding record retention. Please indicate that research data from this study and consent forms will both be retained in separate locked locations for a minimum of three years following the completion of the study.

Describe: 1) the storage location of the research data (separate from consent forms and subject personal data)
2) who will have access to the data
3) how the data will be destroyed
4) the storage location of consent forms and personal data (separate from research data)
5) how the consent forms will be destroyed

Participant consent forms and data collection sheets/computerized files will be stored separately and secured in separate locked locations in the Department of Physical Therapy. Only the investigators will have access to this information. After a period of 3 years from the completion of the study, the consent forms and data collection sheets will be shredded for final disposition and computerized data will be deleted from all disks/drives.

e) Describe procedures to deal with adverse reactions (referrals to helping agencies, procedures for dealing with trauma, etc.).

The investigators or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to his/her health. If subjects consent to participate they will be allowed to terminate their participation in this study at any time without prejudice or jeopardizing any future relationships with the UND Department of Physical Therapy. All investigators are CPR trained. Medical treatment will be provided to each subject as needed, including first aid, CPR, and follow-up care as that provided to a member of the general public in a similar circumstance.

f) Include an explanation of medical treatment available if injury or adverse reaction occurs and responsibility for costs involved.

In the event an adverse event occurs during participation in this study, the subject will be prompted to seek immediate medical attention. All incurred medical expenses will be the responsibility of the subject or the subject's third-party payer.

**III. Benefits of the Study**

Clearly describe the benefits to the subject and to society resulting from this study (such as learning experiences, services received, etc.). **Please note:** extra credit and/or payment are not benefits and should be listed in the Protocol Description section under Methodology.

Possible benefits of this study include but are not limited to: 1) furthering the knowledge concerning the muscle activity and functional positioning of the lower extremity during the wall squat activity which can be used to tailor exercise prescriptions in the clinic; 2) further research may be stimulated; 3) subjects may gain a better understanding of the muscles used during this activity; and 4) improved understanding of the kinematics of the wall squat to aid in the teaching of this activity to students enrolled in the professional physical therapy curriculum. There will be neither cost associated with nor any compensation to any subject who participates in this study.

**IV. Consent Form**

A copy of the consent form must be attached to this proposal. If no consent form is to be used, document the procedures to be used to protect human subjects, and complete the Application for Waiver or Alteration of Informed Consent Requirements. Refer to the RD&C website for further information regarding consent form regulations. **Please note:** Regulations require that all consent forms, and all pages of the consent forms, be kept for a minimum of 3 years after the completion of the study, even if the subject does not continue participation. The consent form must be written in language that can easily be read by the subject population and any use of jargon or technical language should be avoided. **The consent form should be written at no higher than an 8$^{th}$ grade reading level,** and it is recommended that it be written in the third person (please see the examples on the RD&C website). A two inch by two inch blank space must be left on the bottom of each page of the consent form for the IRB approval stamp. The consent form must include the following elements:

a) An introduction of the principal investigator

b) An explanation of the purposes of the research

c) The expected duration of subject participation

d) A brief summary of the project procedures

e) A description of the benefits to the subject/others anticipated from this study

f) A paragraph describing any reasonably foreseeable risks or discomforts to the subject

g) Disclosure of any alternative procedures/treatments that are advantageous to the subject

h) An explanation of compensation/medical treatment available if injury occurs.

i) A description of how confidentiality of subjects and data will be maintained. Indicate that the data and consent forms will be stored in separate locked cabinets for at least three years following the completion of the study. Indicate where, in general, the data and consent documents will be stored and who will have access. The following statement must be included in all consent forms and informational letters: "Only the researcher, the adviser, [if applicable] and people who audit IRB procedures will have access to the data." Please make appropriate additions to the persons that may have access to your research data. Indicate how the data will be disposed of. Be sure to list any mandatory reporting requirements that may require breaking confidentiality.

j) The names, telephone numbers and addresses of two individuals to contact for information (generally the student and student adviser). This information should be included in the following statement: "If you have questions about the research, please call (insert Principal Investigator's name) at (insert phone number of Principal Investigator) or (insert Adviser's name) at (insert Adviser's phone number). If you have any other questions or concerns, please call Research Development and Compliance at 777-4279."

k) If applicable: an explanation of who to contact in the event of a research-related injury to the subject.

l) If applicable: an explanation of financial interest must be included.

m) Regarding participation in the study:

1) An indication that participation is voluntary and that no penalties or loss of benefits will result from refusal to participate.

2) An indication that the subject may discontinue participation at any time without penalty, with an explanation of how they can discontinue participation.

3) An explanation of circumstances which may result in the termination of a subject's participation in the study.

4) A description of any anticipated costs to the subject.

5) A statement indicating whether the subject will be informed of the findings of the study.

6) A statement indicating that the subject will receive a copy of the consent form.

See Attached Form

**By signing below, you are verifying that the information provided in the Human Subjects Review Form and attached information is accurate and that the project will be completed as indicated.**

**Signatures:**

(Principal Investigators) Date:

(Student Adviser) Date:

**Requirements for submitting proposals:**
Additional information can be found on the IRB web site at **www.und.nodak.edu/dept/orpd/regucomm/IRB/index.html.**

Original Proposals and all attachments should be submitted to Research Development and Compliance, P.O. Box 7134, Grand Forks, ND 58202-7134, or brought to Room 105, Twamley Hall.

Prior to receiving IRB approval, researchers must complete the required IRB human subjects' education. Please go to http://www.und.nodak.edu/dept/orpd/regucomm/IRB/IRBEducation.htm for more information.

The criteria for determining what category your proposal will be reviewed under is listed on page 3 of the IRB Checklist. Your reviewer will assign a review category to your proposal. Should your protocol require full Board review, you will need to provide additional copies. Further information can be found on the RD&C website regarding required copies and IRB review categories, or you may call the RD&C office at 701 777-4279.

# APPENDIX E

## RELEASE STATEMENT

I hereby give my permission to the University of North Dakota, its agents, successors, assigns, clients and purchasers of its services and/or products, to use my photograph (whether still, motion or television)

Name:

Signed:_____

Date:_____

Address:_____

City:_____

State and Zipcode:_____

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